USDA, FOREST SERVICE: PROGRESS REPORT 73-1 COMPARATIVE STUDIES OF SPRAY DEPOSIT DISTRIBUTION OF ZECTRAN AND PYRETHRINS USED AGAINST THE DOUGLAS-FIR TUSSOCK MOTH IN 1972

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COMPARATIVE STUDIES OF SPRAY DEPOSIT DISTRIBUTION OF ZECTRAN AND PYRETHRINS USED AGAINST THE DOUGLAS-FIR TUSSOCK MOTH IN 1972.

by

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SUMMARY

Open-ground airport tests and field experiments were conducted to determine the effectiveness of Zectran and stabilized pyrethrins for controlling the Douglas-fir tussock moth. The spray deposit assessment indicated the spray coverage of the aerial applications of the two insecticides.

The Zectran formulation containing 0.15 pound of Zectran per gallon of spray was applied to three test plots; one in the State of Washington and two in the State of Oregon. In an additional test plot in Oregon, a Zectran concentration of 0.3 pound per gallon was applied. The application rate for all the Zectran treatments was 1 gallon per acre.

A stabilized pyrethrins formulation containing 0.1 pound of pyrethrins per gallon was applied to one test plot in the State of Washington. Two pyrethrins treatments were applied 7 days apart to the same test plot. The application rate for both pyrethrins treatments was 0.5 gallon per acre.

The results of the spray deposit assessments show that the deposit coverage was adequate for the Zectran treatments. The average deposit reaching the ground was 0.494 gallons per acre for the Washington experiment and 0.316 for the experiment conducted in Oregon. The deposit coverage achieved with the pyrethrins application was considerably less, with only 14 percent of the spray reaching the ground in the open.

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INTRODUCTION

Periodic outbreaks of the Douglas-fir tussock moth, Hemerocampa pseudotsugata, caused considerable damage to the fir forests of the Pacific Northwest. Since the banning of DDT for forest use, there has been no registered insecticide available for controlling the Douglas-fir tussock moth. Zectran and stabilized pyrethrins were selected as candidate insecticides for field experiments to test their effectiveness against the tussock moth. Both insecticides are nonpersistent, breaking down in light and air within a few hours.

The field experiment was a cooperative project of Region 6, the Insecticide Evaluation Project (IEP) of the PSW, and the Aerial Application Project (AAP) of the PNW, the Oregon Department of Forestry, and the Washington State Department of Natural Resources. The general objective of the AAP was to provide technical input for a successful field experiment comparing the use of Zectran and pyrethrins for the control of the Douglas-fir tussock moth.

Whey using short-lived insecticides, precise aerial application is especially important to ensure satisfactory coverage to

obtain high insect control. Deposit assessment provides an adequate measure of the application technique, and is therefore a necessary constituent of any field experiment testing the effectiveness of insecticides. This report describes the results of spray tests conducted at the airport in Corvallis, Oregon, and the spray deposit assessment from field experiments in Washington and Oregon. The correlation of the amount of spray deposit with the degree of larval mortalities for the field experiments will be published elsewhere.

AIRPORT TESTS

The open-ground tests were conducted at the 50-acre aerial application site at the Corvallis Municipal Airport. A Bell 47G helicopter was contracted for the tests. The Zectran test was conducted April 25, 1972, and the pyrethrins test was April 26. A second pyrethrins test was made June 13. A 500-foot-long rotating platform facilitated the performance of the tests and allowed for either upwind or crosswind test flights.

OBJECTIVES. The specific objectives of the airport tests were as follows:

1. To calibrate and determine the performance of selected spray equipment and spray formulations.
2. To determine the spray atomization and physical and biological swath widths for both insecticides.
3. To test and improve qualitative and quantitative deposit assessment methods for Zectran and pyrethrins formulations.

MATERIALS AND METHODS.

Calibration--The spray equipment was calibrated to deliver 1.0 and 0.5 gallons per acre of the Zectran and pyrethrins formulations, respectively, assuming an effective swath width of 100 feet and an air speed of 45 mph. The flow rates for the desired nozzle tips (TeeJet 8003 and 80015) were determined using a small capacity (1 gallon) hand sprayer. The formulations were sprayed for one minute intervals. The spray was collected and measured with a graduate cylinder thus providing the flow rate per minute.

Design--Three test flights were conducted using the Zectran formulation. The formulation was sprayed through twenty-two, 8003 Flat Spray TeeJet (Spraying Systems Co.)[1/] nozzles with an ambient spray pressure of 55-60 psi. Four test flights were flown during the first pyrethrins test: three flights with a spray pressure of 60 psi and one with 40 psi. TeeJet 8003 nozzles were used for the first pyrethrins test. In the second pyrethrins test, three test flights were made using 80015 TeeJet nozzles. Two flights were made with a spray pressure of 60 psi and one with 40 psi. The nozzle orifices were pointed forward and down 45° to the thrust line of the helicopter for all the test flights.

Sampling stations for each flight were set up at 10-foot intervals along the 500-foot rotating platform. Each sampling station consisted of two aluminum plates (6" X 6") and one white Kromekote (5" X 4") card. For the second pyrethrins test, a magnesium oxide (MgO) coated slide was also placed at each sampling station. Twenty minutes after each flight, the plates and cards were collected for laboratory analysis. The deposit, eluted from the aluminum plates, provided data for the physical swath widths and deposit patterns. The spray atomization was determined from the deposit on the white cards, and in the case of the second pyrethrins test, from the deposit on the MgO coated slides.

1/ Mention of the name of the manufacturer or a product does not constitute endorsement by the U.S. Department of Agriculture.

On some test flights for each insecticide, a potted Douglas-fir seedling (1-1.5 feet high), holding 20 second and third-instar tussock moth larvae, and a petri dish, containing 10 larvae, were also placed at each sampling station. Pinolene was wiped on the inside edge of the petri dishes so the larvae could not crawl out of the dish. The insects were placed on the young fir trees three or four days prior to the spray tests to allow time for the larvae to become settled on the foliage. Perforated plastic bags were placed over the plants to act as cages. At the test site, the bags were removed just prior to spraying and replaced immediately after the deposition of the insecticide. Any larvae that had fallen from the trees either because of the spray application (knock down), handling, or wind, were placed back on the tree before rebagging. The insects and plants were held at the laboratory for bioassay.

Formulations--The Zectran formulation consisted of one part FS-15 (Zectran-Dowanol TPM concentrate) mixed with nine parts fuel oil #2. The resulting concentration of Zectran was 0.15 pound per gallon of spray. To this finished formulation, 3.785 grams (0.1%w/v) of the fluorescent tracer, Rhodamine B Extra base (GAF Corp.), per gallon of spray was added to facilitate deposit assessment.

The pre-mixed pyrethrins formulation (MGK pyrethrins formulation 7076) was furnished by the McLaughlin Gormley King Company. The ingredients were: 1.44% pyrethrins (.1 lb/gal), 5.6% petroleum

distillate, 89.20% heavy mineral oil, and 3.60% inert ingredients (stabilizers). To each gallon of pyrethrins formulation, 3.785 grams each of Fluoranthene (Aldrich Chemical Co.) and Oil Red dye (Allied Chemical Co.) were added for deposit assessment purposes.

Tank samples of the complete formulations were collected prior to spraying to determine the actual concentration of the fluorescent tracers.

Spray Deposit Assessment--The spray atomization was determined by the drop-size spectra method (Maksymiuk, 1964).

In the laboratory, the spray deposit was washed from each of the aluminum plates with 10 ml of the appropriate solvent: 95% ethanol for the Zectran formulation, and spectroscopic grade benzene for the pyrethrins formulation. The concentration (g/ml) of the fluorescent tracers was measured with a Model 430 Turner Spectrofluorometer. The concentration values (g/ml) were corrected for background fluorescence from pre-spray samples and percent recovery. The percent recovery had been predetermined by applying known volumes of the formulations to aluminum plates, and the deposit was then determined by the method described above. The comparison of known deposit to calculated amount gave the percent recovery. The percent recovery from the aluminum plates was virtually 100% for both Zectran and pyrethrins formulations. The deposit in terms of gallons per acre (gpa), per sampling station, was calculated using the actual tracer concentrations from the

tank samples, the amount of tracer removed from the plates, and the area of the plates.

$$GPA = \left(\frac{g.dye}{ml} \times 10^{-7}\right) \frac{(ml\ of\ wash)\ (4.356 \times 10^4\ sq\ ft/acre)}{(g.\ dye/gal)\ (.25\ sq\ ft/plate)} \quad (1)$$

The number of spray drops per sq. cm. of Zectran deposited on the white Kromekote cards were counted under a dissecting microscope using an ultraviolet light for illumination of the fluorescent deposit. Since the Fluoranthene used with the pyrethrins formulation was colorless, the red dye was used to make the deposit visible. The large spread of the mineral oil formulation caused the drops to spread excessively, making them almost invisible. However, when a light was directed up, through the card, the drops could be counted with the aid of a microscope.

The deposit (gpa) per station was plotted versus the distance across the spray swath. The resulting graphs illustrated the deposit patterns of the spray.

Biological Assessment--The mortalities, of the Douglas-fir tussock moth larvae caged on the potted trees, were determined 6 days after the day of spraying. The survival ratio per tree was determined using the number of insects, both living and dead, found on the trees. The larvae in the petri dishes were transferred to clean dishes containing artificial media. The dead insects were counted and removed daily for 10 days after the spray test. Ten control (untreated) trees and 20 unsprayed petri dishes were used to determine the natural mortality.

Mortality across the spray swath indicated the biological swath widths. On the second pyrethrins test, no petri dishes with larvae were used and an initial 4-day larval mortality on the trees was determined.

RESULTS AND DISCUSSION

Calibration--The flow rates for both the Zectran and pyrethrins formulations are summarized in Table 1 for two spray pressures and two nozzle sizes. Since the flow rates of the two formulations were approximately equal, the fuel oil TPM mixture (one part TPM in nine parts fuel oil #2) was always used for the initial calibrations of the spray equipment, thus avoiding the handling of and exposure to large quantities of toxic materials.

Meteorological--Meteorological and other pertinent data for the open-ground airport tests are summarized in Table 2. The wind direction and speed were monitored continuously during the tests. Helium inflated balloons were used to determine the wind movements at the height of 50 feet. In general the meteorological conditions were significantly more favorable for the pyrethrins tests than for the Zectran test.

Atomization--Three estimates of the mass median diameter (mmd) were made for each test flight (Table 3). The average mmd for the three Zectran flights was 155 with a standard deviation of 16.6 microns.

Table 1.--Summary of flow rate data for Zectran and pyrethrins formulations.

Nozzle size	Spray pressure, psi	Flow rate/nozzle, gallons per min.			
		Pyrethrins formulation	Zectran formulation[a/]	H_2O	Fuel oil #2
8003	40	0.3300 (.0030)[b/]	0.3274 (.0004)	0.3031 (.0038)	0.3194 (.0022)
8003	60	0.3949 (.0031)	0.3978 (.0043)	0.3754 (.0020)	0.3880 (.0035)
80015	40	0.1532 (.0000)	-	-	0.1501 (.0002)
80015	60	0.1925 (.0023)	-	-	0.1886 (.0009)

a/ For the calibrations, the Zectran formulation contained only Dowanol TPM and fuel oil #2 mixed one to nine.

b/ The standard errors of the means are at the 5 percent probability level.

Table 2.--Summary of meteorological and other pertinent data from the open-ground tests.

Insecticide & date	Flight no.	Time, a.m.	Appl. rate, gpa	Nozzles size	Nozzles no.	Boom pressure, psi	Meteorological conditions: temperature (°F) @2 ft.	temperature (°F) @4 ft.	temperature (°F) @50 ft.	wind mph.	wind direct.	weather
Zectran 4/25/72	1	6:30	1.0	8003	22	60	45.0	44.0	44.0	5-8	SW	cloudy & showers
	2	7:55	1.0	8003	22	55-60	50.0	50.5	51.0	4-6	SW	cloudy & showers
	3	10:10	1.0	8003	22	55	54.0	55.0	-	1-2	NE	cloudy
Pyrethrins 4/26/72	1	6:10	0.5	8003	11	55	36.0	36.0	37.0	2	NE	sunny
	2	7:00	0.5	8003	11	54	54.0	46.0	47.0	0-1	W	sunny
	3	7:55	0.5	8003	11	53-54	51.0	48.5	-	4-5	N	sunny
	4	8:50	0.5	8003	14	40	55.0	53.0	-	4-5	NE	sunny
Pyrethrins 6/13/72	1	6:25	0.5	80015	23	60	53.0	51.0	52.0	1	NW	sunny
	2	7:23	0.5	80015	23	60	61.0	64.0	57.0	2	NW	clear
	3	8:50	0.5	80015	29	40	65.0	63.5	58.0	3-4	NE	cloudy

Table 3.--Atomization data from the open-ground tests.

Insecticide	Flight no.	Spray press., psi.	Atomization (mmd), microns	Surface
Zectran	1	60	136 (6.8)[a/]	Kromekote card
	2	55-60	167 (10.8)	Kromekote card
	3	55	162 (61.2)	Kromekote card
Pyrethrins(1st)	1	55	275 (51.2)	Kromekote card
	2	54	205 (80.4)	Kromekote card
	3	53-54	322 (88.4)	Kromekote card
	4	40	258 (78.8)	Kromekote card
Pyrethrins(2nd)	1	60	210 (39.2)	Kromekote card
			159	MgO slide
	2	60	283 (34.0)	Kromekote card
			186	MgO slide
	3	40	263 (18.8)	Kromekote card
			236	MgO slide

a/ The values in parentheses are the standard error of the mean at the 5 percent probability level.

The results of the first pyrethrins test were confusing since the mmd obtained with 40 psi (258 microns) was actually lower than the average mmd obtained with 60 psi (267 microns). However, the large variations involved make the small difference insignificant, especially since only one flight was made at 40 psi. Since the large spreading ability of the mineral oil formulation was not a problem with the MgO coated slides, as it was with the cards, the estimates of the atomization using these slides are more accurate than estimates from the white cards. In the second pyrethrins test (80015 nozzles), the average mmd using 60 psi was 172 microns while 40 psi resulted in a 236 micron mmd (MgO data in Table 3). These results are more in line with the usual spray pressure-atomization relationship. These results showed that the MgO coated slides should be used during the field experiments with the pyrethrins formulation for an accurate determination of the spray atomization.

Spray Deposit Assessment--The physical swath widths and deposit patterns for the various tests are shown in Figures 1-3. The effect of the meteorological conditions (Table 2) especially the wind speed, are very apparent on the deposit of the Zectran formulation (Figure 1). Flight #3, conducted under favorable meteorological conditions, resulted in higher deposit across the swath. The same effects are seen in the two pyrethrins tests--favorable weather conditions generally resulted in higher deposit.

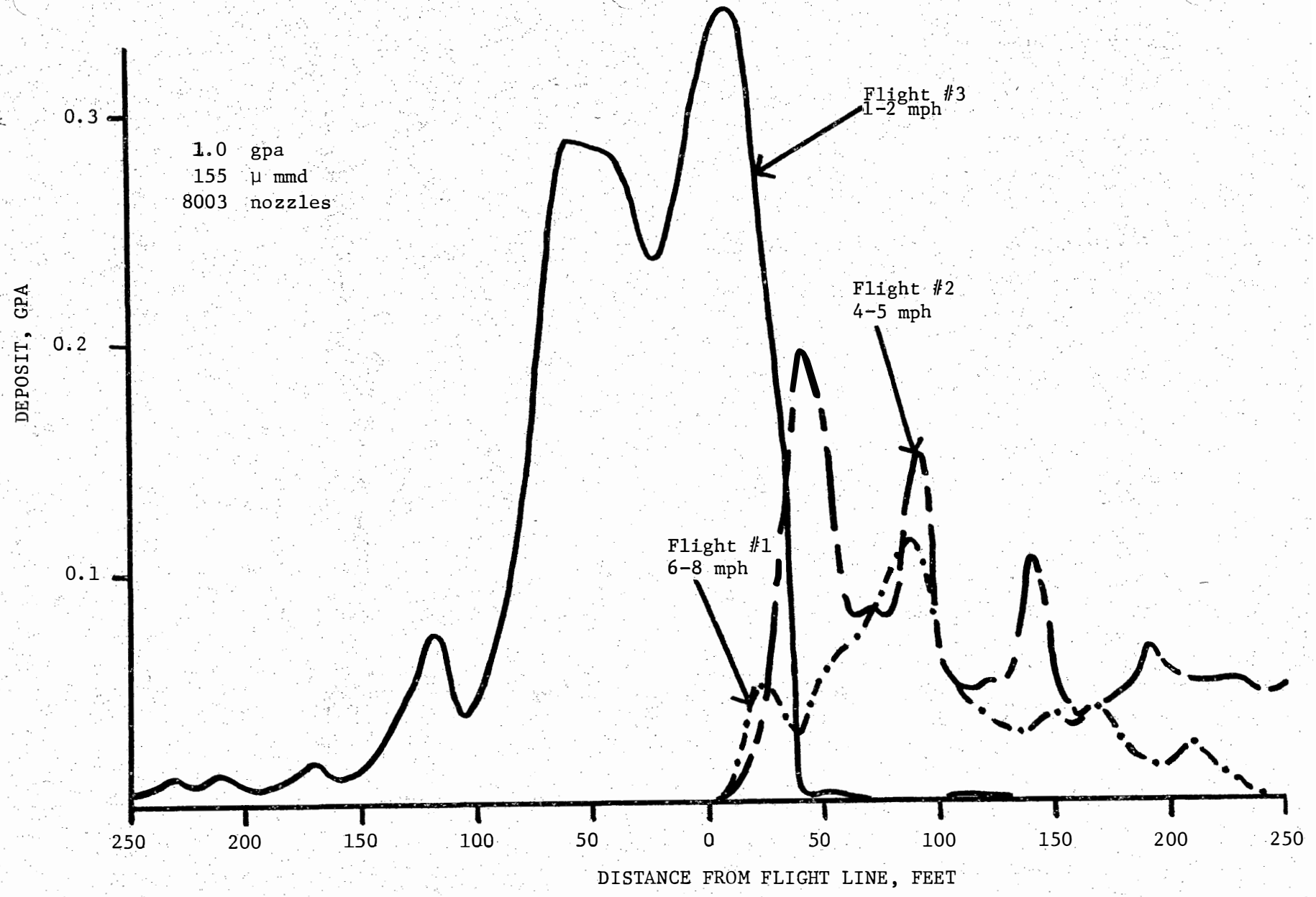

Figure 1.--Deposit patterns of the Zectran formulation across the spray swath of the open-ground tests.

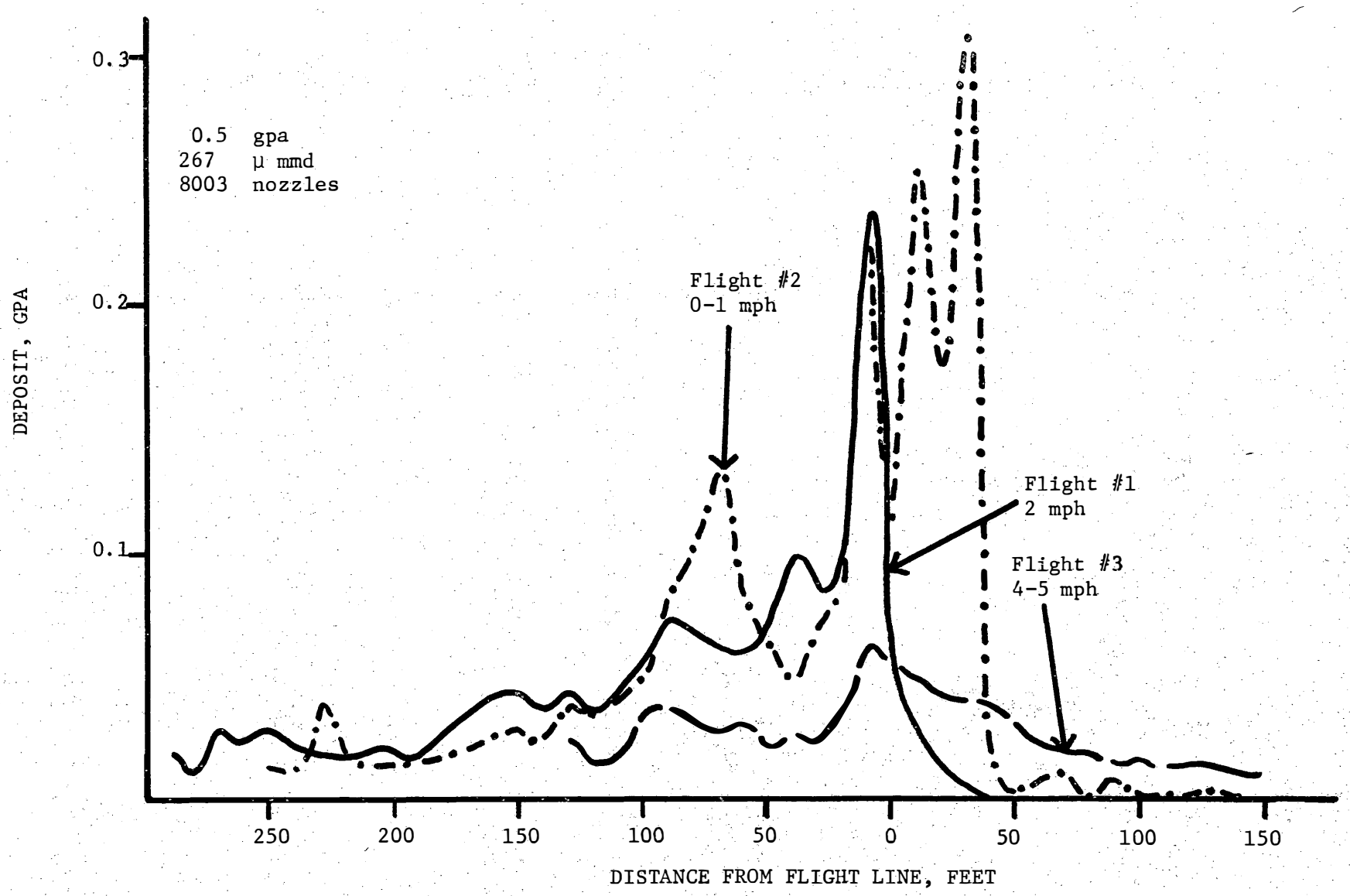

Figure 2.--Deposit patterns of the pyrethrins formulation across the spray swath using 8003 nozzle tips.

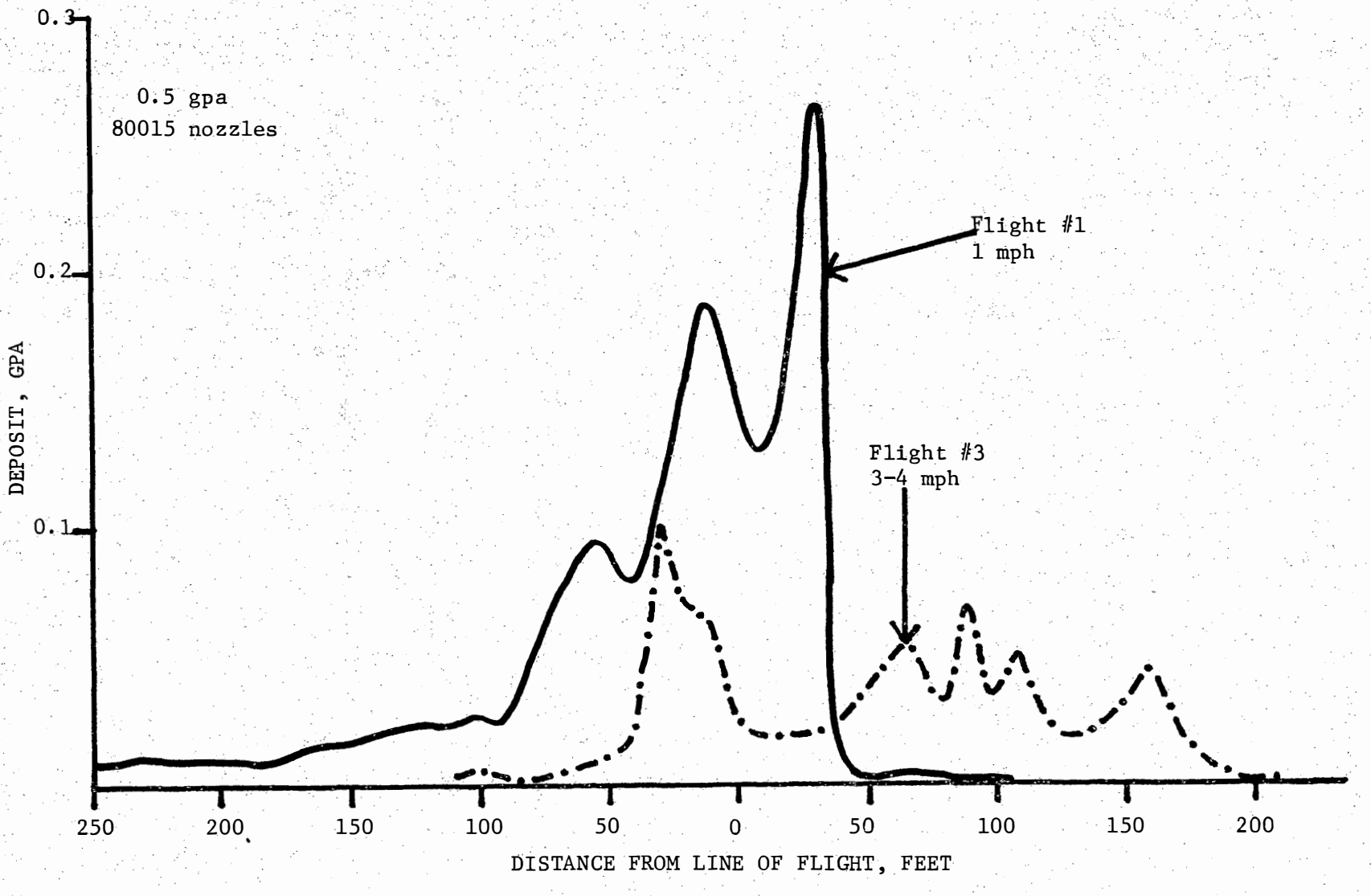

Figure 3.--Deposit patterns of the pyrethrins formulation across the spray swath using 80015 nozzle tips.

The average spray deposit and Douglas-fir tussock moth larval mortalities, across 100-and 200-foot swaths, are summarized for each test flight in Table 4. The deposit from flight #4 of the first pyrethrins test series was not analyzed because of the lack of time and the need to reuse the aluminum plates for field tests. Since the atomizations resulting from the 60-psi applications (flights 1-3) were coarser than desired (Table 3), deposit information from the 40-psi flight would not yeild any new information needed to make technical recommendations for the field test.

In the second pyrethrins test series (using 80015 nozzle tips), the 60-psi spray pressure not only resulted in a finer atomization (Table 3), but also produced higher average deposit (gpa) across the 100-foot swath width, than resulted with the 40-psi spray pressure (Table 4). The striking result, however, was the insect mortality (Table 4). The 40-psi flight had the higher mortality even with the lower deposit. It is hard to evaluate the differences between the 40-and 60-psi applications because the weather conditions were not consistent and no replicate flights were conducted with the insects at the two spray pressures. Since the flight with 40-psi pressure gave the higher mortality, the decision was made to use this pressure with the 80015 nozzles for the pyrethrins field experiment.

The second interesting result of the airport tests was the higher larval mortality achieved with the Zectran. Here again, the variable weather conditions, the different insecticide concen-

Table 4.--Summary of deposit and Douglas-fir tussock moth mortality for open-ground airport tests.

Insecticide	Flight no.	Mean deposit, gpa		Ave. corrected % mortality	
		100 ft. swath	200 ft. swath	100 ft. swath	200 ft. swath
Zectran	1	0.057	0.042	99.5	97.5
	2	0.097	0.076	100	-
	3	0.277	0.167	-	-
Pyrethrins#1	1	0.086	0.061	72.1	67.0
	2	0.142	0.095	52.2	-
	3	0.038	0.032	-	-
	4	not analysed			
Pyrethrins#2	1	0.137	0.0832	68.7	42.1
	2	0.044	0.040	84.1	77.2

trations (0.15 lb Zectran/gal vs. 0.1 lb pyrethrins/gal), and application rates (gpa) make any true comparison of the two insecticides impossible.

FIELD EXPERIMENT IN WASHINGTON

OBJECTIVES. The specific objectives of the AAP for the field experiment were as follows:

1. To provide quantitative deposit assessment data for the evaluation of the effectiveness of the two insecticides.
2. To detect, if any, the presence of spray drift in the check plots.
3. To test and improve the spray deposit assessment techniques.
4. To attempt to correlate the results of the airport tests with the results of the field experiments.

MATERIALS AND METHODS.

Area--The Zectran plot contained 400 acres of predominately second growth Douglas-fir forest. The treatment plot was located near Riverside, Washington, with the check area positioned about two miles from the treated area. The pyrethrins test was conducted on a plot located near Oroville, Washington, containing 345 acres of mainly second growth Douglas-fir. The check plot was located about 3/4 of a mile from the spray plot.

Design--One treatment of 0.15 pound of Zectran per acre was applied to the Zectran plot on June 27, 1972. The Zectran formulation was applied at the rate of one gallon per acre. One treatment of 0.05 pound of stabilized pyrethrins per acre was applied at the Oroville plot on June 22, 1972. The application rate was 0.5 gallons per acre. A second pyrethrins application was made

seven days after the original spraying, at the same dosage rate. Both insecticides were applied when most larvae were in the second and third instars.

Equipment--A Bell 47G helicopter equipped with conventional Simplex spraying equipment was contracted for the tests by R-6. Twenty-two, 8003 TeeJet nozzles were used to deliver the Zectran formulation. The nozzle orifices were directed backward 180° to the thrust line of the aircraft. The spray pressure was 60 psi, and the spraying speed was 45 mph. The pyrethrins formulation was delivered through twenty-nine, 80015 Flat Spray TeeJet nozzles with a spray pressure of 40 psi. The spraying speed of the helicopter was 45 mph. The nozzle orifices were directed forward and down 45° to the thrust line of the helicopter.

Formulation--The same formulations were used as described for the airport tests. The formulations were mixed, the day before each test, in a 250 gallon mixing tank provided by the contractor.

Tank samples of the formulations were collected prior to spraying for bioassay (IEP) and to determine the actual concentration of the fluorescent tracers (AAP).

Spray Application--Both treatment plots were sprayed in about the same manner. The helicopter sprayed up and down hill, moving across the plots with 100-foot spray swaths. Flagmen marked the swath spacings, and the corners of the plots were identified with large fluorescent orange markers. The spraying height was about 50 feet above the tree tops. An observation helicopter assisted

the spray aircraft to line-up the swaths. The flagmen, weathermen, helispot, and observation helicopter were in constant radio contact. In general, the weather conditions were favorable for both Zectran and pyrethrins applications.

Insect Sampling--All Douglas-fir tussock moth population assessments were conducted by personnel from Region 6 under the direction of Dr. Carroll Williams of the PSW station. The mortality data from these tests were analyzed, and the results will be published by the Pacific Southwest Forest and Range Experiment Station.

Spray Deposit Sampling--Within the treatment and check plots, four clusters of ten trees each were located along a rough transect, about 500 yards long, perpendicular to the flight line of the helicopter. Each cluster contained about a 3 X 5 chain area, and the clusters were separated from each other by at least five-chain intervals. These ten trees were sampled for insect mortality and spray deposit. The sample trees were selected, based on their size (20-50 feet in height) and accessibility for sampling (in open or semi-open situation). Two aluminum plates (6" X 6") and one white Kromekote card (4" X 5") were placed under each of the 40 sampled trees in each treatment plot. The plates and cards were positioned at the ground level under the trees, approximately below the midcrown of the trees---one aluminum plate and the white card on the north side and the other aluminum plate on the south side of the tree. Another pair of

aluminum plates and a white card were placed in the nearest adjacent opening around each sample tree. This design allowed for a comparison of the deposit reaching the ground, both in the open and under the trees. The plates and cards were placed in the field the day before spraying. Immediately after the spray application, the pairs of aluminum plates were collected, placed face-to-face (deposit sides together), and stored in slotted boxes for transportation.

For the first pyrethrins application, magnesium oxide coated slides were also placed in the open with the aluminum plates and white cards. The MgO slides were used to determine the spray atomization.

Foliage samples were also collected immediately after the spray application. The samples consisted of four, 10-inch twigs taken from the midcrown of each sample tree with a pole pruner. These samples were collected from the four cardinal directions of the trees and placed in brown paper bags. The tree number and sample direction (north, south, east, west) were recorded on each bag. The bagged foliage samples were transported to the Corvallis laboratory for spray analysis.

Pre-spray foliage samples were collected at random throughout the treatment plots the day before each spray application for the determination of background fluorescence. These samples were used to determine the extent of natural fluorescence occurring on the foliage (background).

Spray Drift Sampling--The one check (control) plot for each insecticide was sampled for drift using aluminum plates and white Kromekote cards. The plates and cards were placed in the open along sample lines within the clusters of sample trees. The sampling units, of one white card and a pair of aluminum plates, were spaced 50 feet apart along the sample lines.

Additional Deposit Sampling--In the Zectran plot, a fifth cluster of ten trees was selected for intensive deposit sampling. Five trees were in open to semi-open situations and five other trees were in closed canopy situations. The trees were chosen such that each open tree was roughly paired with a closed canopy tree. Similarly to other sample trees, aluminum plates and white cards were placed under the trees, but only one set of plates was placed in the open for each tree pair. Foliage samples were collected from the top, the four cardinal directions of the lower crown, and midcrown of each tree. The samples were bagged, and the tree number and sample locations recorded on the bags. This additional deposit sampling was conducted to evaluate the current spray deposit sampling procedure for tree foliage.

Spray Deposit Analysis--The deposit on the white Kromekote cards and MgO coated slides was analyzed for the spray atomization. The spray atomization was determined by the drop-size spectra method (Maksymiuk, 1964).

The qualitative and quantitative analyses of the deposit on the aluminum plates and white cards was conducted as described for the airport tests.

For the foliage samples, 100 needles were randomly selected from each foliage sample, after the samples had been dried. The needles were weighed, and the spray deposit was removed by washing with 10 ml of solvent---30% ethanol for the Zectran formulation and spectroscopic grade benzene for the pyrethrins formulation. The concentration (g/ml) of fluorescent tracer was measured with a Model 430 Turner Spectrofluorometer. The concentrations were corrected for background fluorescence, from the average of the pre-spray samples, and percent recovery. The percent recoveries were 55.4 ± 5.0%[2/] and 81.5 ± 1.0% respectively, for the fluoranthene in the pyrethrins formulation and for the Rhodamine B Extra base in the Zectran formulation. The amount of insecticide on the foliage in terms of micrograms (µg) per 100-needle sample, was estimated from the amount of tracer removed from the needles and the assumed insecticide concentrations. The tank concentrations of Zectran and pyrethrins were assumed to be 0.15 pound Zectran per gallon and 0.1 pound of pyrethrins per gallon for the respective formulations.

RESULTS AND DISCUSSION.

Atomization--The average mass median diameter (mmd) for the Zectran application was determined from three separate estimates. The average mmd of the spray reaching the ground was 208 microns.

2/ Standard error of the mean is given at the 5 percent probability level throughout this report.

The mmd of the Zectran formulation is not a true one-application result. Due to a faulty pressure gauge, the initial application rate was somewhat less than one gallon per acre (probably closer to 0.5 or 0.7 gpa). The helicopter applied the entire first load (70 gallons), before the problem was discovered. The spray pressure was increased to give the proper flow rate, and the area was resprayed to give the total dose of one gallon per acre. Therefore, the treatment was the result of two applications---one at a reduced spray pressure which would cause larger drops and the other at the specified spray pressure.

For the first pyrethrins application, the mmd was determined using two sampling surfaces, the white Kromekote cards and the magnesium oxide coated slides. The estimates computed from the white cards are suspect since the large spread factor of the formulation containing mineral oil made the sizing of the spot diameters difficult. The mean mmd determined from the deposit on the white cards was 319 microns. The atomization estimated from the MgO coated slides was 200 microns. No MgO slides were available for the second application of pyrethrins, however, the estimated mmd from the Kromekote cards was 250 microns.

Spray Deposit Assessment--Zectran--The summaries of the deposit data for the Zectran treatment are shown in Tables 5 and 6. Complete deposit data are listed in Appendixes A and B. In Appendix A, the data for the foliage samples represent the average of the

Table 5.--Summary of the amount of Zectran spray deposit recovered from the aluminum plates and the number of drops counted on the white Kromekote cards.

Cluster	Deposit			
	in the open		under the trees	
	gpa	drops/cm^2	gpa	drops/cm^2
1	0.613 (.115)[a/]	95.7 (18.6)	0.230 (.093)	67.7 (16.9)
2	0.525 (.091)	48.6 (5.0)	0.286 (.080)	42.2 (7.1)
3	0.353 (.060)	74.0 (8.1)	0.174 (.041)	67.4 (9.2)
4	0.486 (.096)	73.4 (6.2)	0.168 (.052)	55.7 (5.4)

a/ The values in parentheses are the standard errors of the mean at the 5 percent probability level.

Table 6.--Summary of the estimated amount of spray recovered from the foliage samples obtained from the four cardinal directions of the tree midcrowns.

Direction	Number of samples	Mean Deposit	
		g. dye/10 ml X10-^{5} per 100 needles	estimated µg. Zectran per 100 needles
North	40	4.782 ± 1.172[a/]	8.585 ± 2.104
South	40	3.800 ± 0.889	6.822 ± 1.597
East	40	3.624 ± 0.841	6.506 ± 1.509
West	40	5.239 ± 1.397	9.406 ± 2.509

a/ Standard error of the mean is at the 5 percent probability level.

samples collected from the four cardinal directions per tree. A concentration of 0.15 pound of Zectran per gallon of spray was assumed for the estimates of the micrograms of Zectran on the foliage (µg Zectran/100-needle sample).

Linear regression analysis was used to determine the linear association of the deposit (gpa) on the aluminum plates in the open with (1) the deposit on the foliage (µg Zectran/100 needles), and (2) with the drops per square centimeter (in the open). The relationship between the deposit on the foliage, and the drops per square centimeter found in the open was also determined. Figure 4 shows a plot of gpa versus µg Zectran. The linear regressions of the gpa correlated with the deposit on the foliage (r=0.77) and gpa associated with the drops per centimeter (r=0.57) were significant at the 0.01 level. The linear regression of drops/cm^2 associated with deposit on the foliage (r=0.37) was significant only at the 0.05 level. The high linear regression of deposit on the aluminum plates, with the deposit on the foliage, illustrates that the aluminum plate data provide a good indication of the deposit reaching the trees. The low (r) values encountered with correlations involving the drops per square centimeter can be partially explained by the variation in the drop size spectra. A few large drops result in a higher deposit (in terms of gpa--not coverage) than many small drops.

The distribution of spray deposit, in the sampled area, was quite uniform (Tables 5 and 6); the average deposit (gpa)

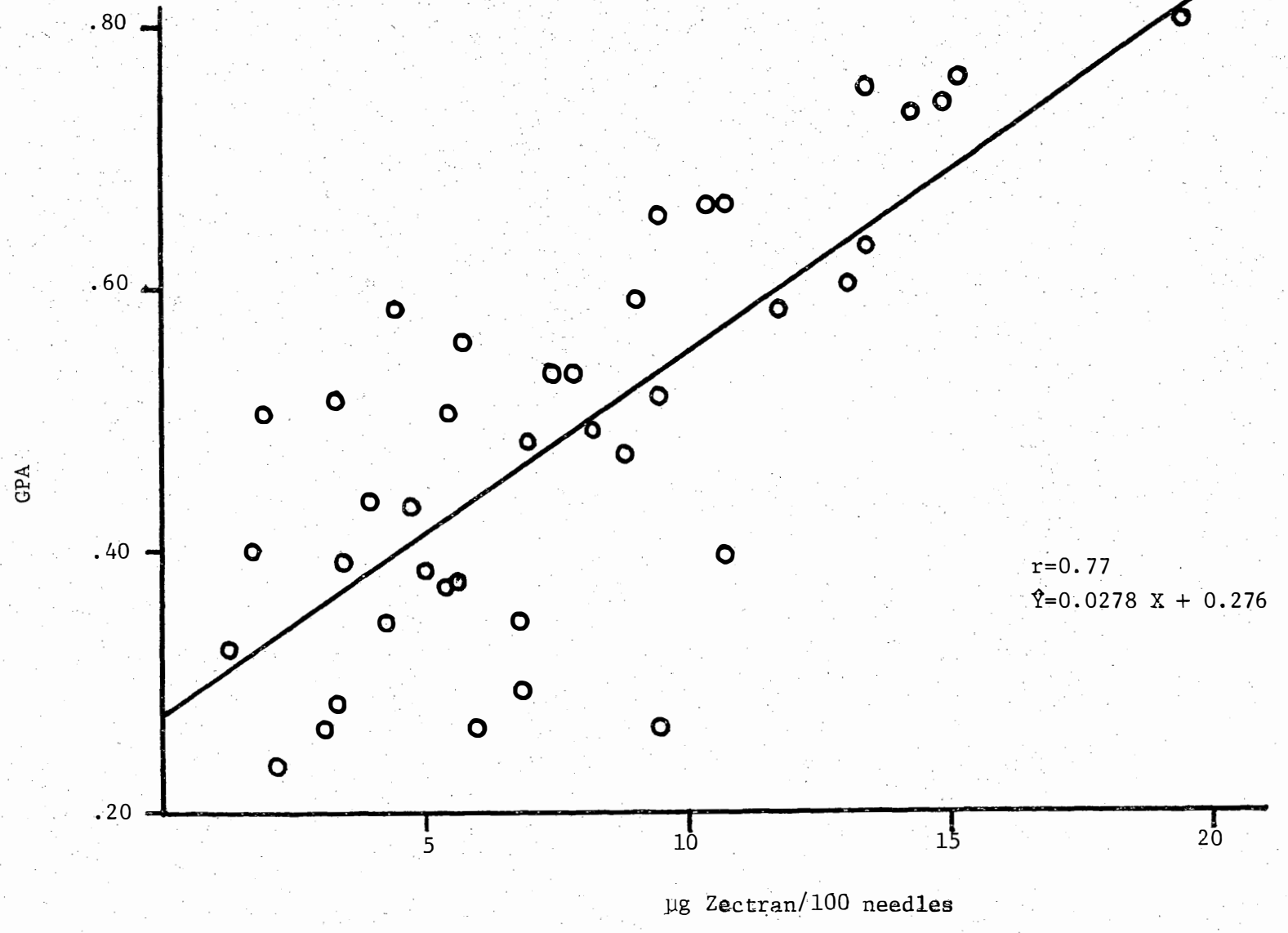

Figure 4.--The relationship between the deposit (gpa) removed from the aluminum plates that were in the open and the deposit recovered from the foliage (µg Zectran/100 needles) of the adjacent trees.

recovered from the aluminum plates, that were in the open areas, was 0.494 ± 0.050. However, analysis of variance showed that the small differences, in the mean deposit among the clusters, were significant at the 0.01 level for both the aluminum plate data and the drops per square centimeter (Table 5). A comparison among the means showed the average deposit in clusters #1 and #2 was significantly higher than clusters #3 and #4 at the 0.01 level. For the drop densities, the average drops/cm^2 for cluster #2 was significantly less than the other three clusters at the 0.01 level. Analysis of variance also showed there was no significant directional dependence on the deposit at either the 0.01 or 0.05 levels (Table 6). This is in contrast to the results found in last year's tests (Maksymiuk, et al., 1971 a, b), in which higher mean deposits were found in the direction of the air mass movements.

The difference in deposit (gpa and drops/cm^2), between samples in the open and samples placed directly under trees, gives a rough estimate of how much spray impinges on the foliage. The average deposit (aluminum plate data) recovered under the trees was 0.215 gpa, or in-other-words, about 43% of the spray filtered through the foliage. However, this does not take into account spray that drifts under the trees. Analysis of variance showed that such differences were highly significant (0.01 level). The average drop size found under the trees was another interesting

result. The average mmd of the drops under the trees was 145 microns compared to 208 microns in the open. The smaller drop size can be explained by either the screening of the tree (the larger drops impinge to a greater extent) or by considering the possible break-up of large drops when they contact the needles.

Pyrethrins--The deposit data for the two pyrethrins applications are summarized in Tables 7 and 8; complete tabulations of the data are listed in Appendixes C-E. In Appendix C a pyrethrins concentration of 0.1 pound per gallon was assumed for the calculation of the estimated micrograms (µg) of pyrethrins per foliage sample of 100 needles. The foliage samples, from the pyrethrins applications, were difficult to analyze since the fluorescent tracer, Fluoranthene, fluoresces in the range where contaminants, such as pitch and dust, cause background problems. These contaminants produced a background reading with the fluorometer that corresponded to 2.59×10^{-8} g/ml (compared to $.045 \times 10^{-8}$ g/ml for the Zectran analysis). The background values were quite variable with a range of 1.20×10^{-8} to 4.12×10^{-8} g/ml. This type of background reduces the sensitivity of the analysis and naturally introduces a certain amount of error in the estimates of the amount of spray recovered from the foliage. This might partially explain the low values of the pyrethrins deposit recovered from the foliage.

Table 7.--Summary of the amount of deposit recovered from the aluminum plates and the number of drops on the white Kromekote cards from the two pyrethrins applications.

Appl.	Cluster	Deposit			
		In the open		under the trees	
		gpa	drops/cm^2	gpa	drops/cm^2
1	1	0.048 (.024)[a/]	5.9 (2.6)	0.021 (.009)	3.4 (1.0)
	2	0.109 (.069)	14.5 (7.3)	0.045 (.029)	10.3 (5.5)
	3	0.102 (.031)	16.8 (4.1)	0.038 (.016)	12.6 (3.1)
	4	0.044 (.030)	7.2 (2.1)	0.017 (.009)	4.3 (1.1)
2	1	0.036 (.028)	3.9 (1.8)	0.021 (.010)	4.0 (2.2)
	2	0.101 (.046)	21.6 (7.5)	0.056 (.020)	13.9 (4.4)
	3	0.066 (.033)	13.9 (5.5)	0.034 (.018)	11.3 (3.4)
	4	0.045 (.016)	11.4 (5.4)	0.032 (.013)	9.5 (4.7)

a/ The values in parentheses are the standard errors of the mean at the 5 percent probability level.

Table 8.--Summary of the estimated amount of spray recovered from the foliage samples collected from the four cardinal directions of the tree midcrowns.---First pyrethrins application only.

Direction	Number of samples	Mean Deposit	
		g. dye/10 ml $X10^{-6}$ per 100 needles	est. µg. pyrethrins per 100 needles
North	40	0.437 ± .525[a/]	5.487 ± 6.585[a/]
South	40	0.412 ± .277	5.177 ± 3.474
East	40	0.292 ± .130	3.666 ± 1.630
West	40	0.326 ± .418	4.096 ± 5.241

a/ Standard errors of the mean are at the 5 percent probability level.

Since the pre-spray background for the second pyrethrins application was even higher than the first (3.43×10^{-8} g/ml), the foliage samples were not processed for the second application (Appendix D).

The linear associations of the deposit on the foliage (µg pyrethrins with (1) the deposit on the aluminum plates (gpa), and with (2) the drops/cm^2 on the white cards, were determined using linear regression analysis. The coefficient of linear correlation (r) were 0.18 and 0.06, respectively, and the linear regressions were not significant. These low linear correlations are most probably the result of inaccurate estimates of the amount of pyrethrins deposit on the foliage, since the correlations between deposit on the plates (gpa) and drops/cm^2 on the white cards gave (r) values of 0.75 and 0.63 for the first and second applications, respectively (Figure 5). Both of these linear regressions were significant at the 0.01 level.

The consistancy of application was about the same for both pyrethrins treatments (Table 7), although the average deposit was less for the second application: 0.076 ± .021/gpa for the first application and 0.062 ± .016/gpa for the second application. Analysis of variance showed there was no significant difference (at the 0.01 level) in the deposit at the ground level (gpa) between the clusters for either application. There was a significant (0.01 level) difference in the mean number of drops/cm^2 among the different clusters for both applications. In the first

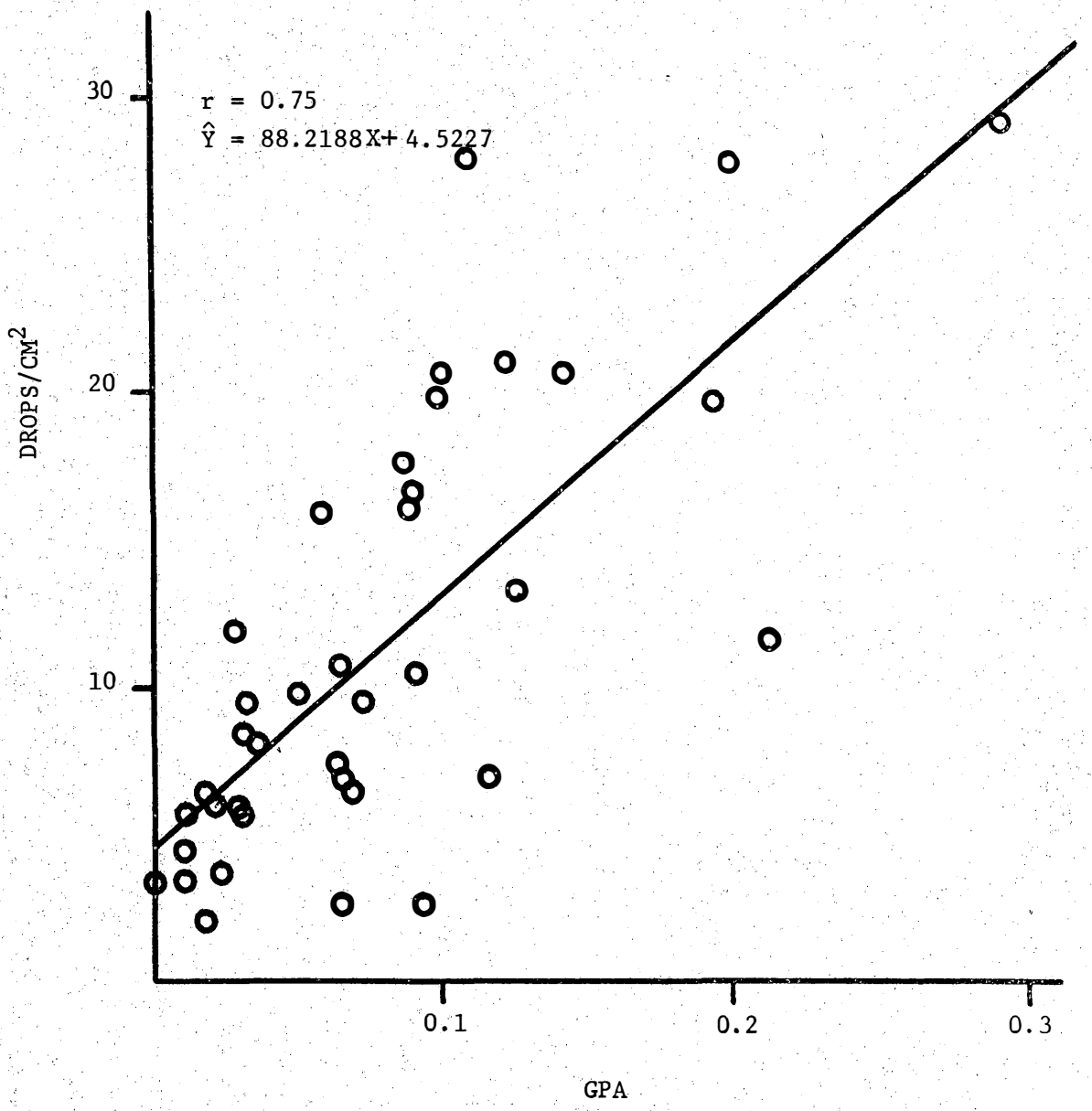

Figure 5.--The association between the drop density (drops/cm^2) and the pyrethrins deposit (gpa) removed from the aluminum plates that were in the open areas.

application, clusters #2 and #3 had a significantly higher drop density than clusters #1 and #4. In the second application, cluster #2 had more, and cluster #1 had fewer drops/cm^2 than the other three clusters. Analysis of variance also showed there was no directional dependance on the deposit removed from the foliage samples for the first application (Table 8).

As was the case with the Zectran treatment, there was significantly higher (0.01 level) deposit recovered in the open than under the trees for both pyrethrins applications (Appendixes C and D). The average mmd of the drops reaching the ground level under the trees (255 microns) was lower than the atomization sampled in the openings (322 microns). Since these mmd estimates were made from Kromekote cards, the actual magnitudes are most likely too large, because of the large spread of the formulation on the Kromekote cards. However, the trend is the same as that found with the Zectran treatment.

Drift Assessment--The average deposit, recovered from the aluminum plates placed in the Zectran check plot (control), was 0.0003 ± .00006 gpa. This quantity was greater than the average pre-spray background value of 0.00021 ± .00005 gpa by at least one standard deviation. A t-test also showed these means were different at the 0.1 level. Although these differences are very small, they do show there was detectable drift into the check area. Since the actual amount of drift was so small, no insect mortality can be attributed to drift in the Zectran control plot.

For the first pyrethrins application, the average deposit found in the control plot, 0.0029 gpa, was not appreciably different from the background value of 0.0024 ± 0.0010 gpa. The two means did not differ by more than one standard deviation. For the second pyrethrins application, the average deposit found in the check plot was actually lower than the average pre-spray background sample. Therefore, it is safe to conclude that there was no drift into the check plot with either pyrethrins application.

Additional Deposit Study--Data for the deposit removed from various tree location and tree canopy situations of the fifth Zectran cluster are shown in Table 9. Tree numbers one through five were closed canopy, while trees six through ten were open. Analysis of variance showed there was no statistical difference between the deposit removed from the open or closed canopy trees. There was also no statistical deposit dependence on sample location within the tree (top, midcrown, or lower crown), Figure 6. The data from these ten trees at least indicate that our sampling method, of four midcrown samples collected from open or semi-open trees, adaquately approximates the tree populations. However, such inferences should be made cautiously when dealing with such small sample sizes.

Table 9.--Estimated Zectran deposit sampled at various tree locations.

Canopy type	Tree no.	Estimated deposit, µg Zectran per 100 needles							
		top	midcrown				lower crown			
			north	south	east	west	north	south	east	west
Closed	D 1	7.9813	1.7926	3.3777	1.7733	.2849	7.9555	1.9087	5.9294	1.2515
	D 2	7.0722	5.6177	2.3725	7.0723	1.3094	22.9158	7.0723	12.0072	6.5529
	D 3	14.9421	1.8700	9.5137	24.8897	7.0723	16.7861	10.1891	25.5132	4.7347
	D 4	8.2410	8.8904	5.1503	2.2566	1.4446	.5944	1.6767	.6715	.5362
	D 5	15.2537	10.7083	2.7977	10.1891	2.4111	.8649	9.4098	3.3389	13.8253
Open	D 6	9.1241	2.0825	5.2540	7.1761	4.8386	1.3867	7.3318	8.2670	15.1239
	D 7	1.7927	17.3057	13.3059	19.3836	23.5391	12.0072	8.1112	6.5529	11.4877
	D 8	8.0593	16.9420	6.5529	9.1501	4.6307	6.7086	4.4750	3.5128	3.1213
	D 9	4.6377	3.1533	1.9859	1.6767	.7682	1.4446	2.1405	2.1213	1.1161
	D10	17.5133	8.8904	5.5139	10.4488	7.3318	3.3582	11.7473	9.6694	16.4224

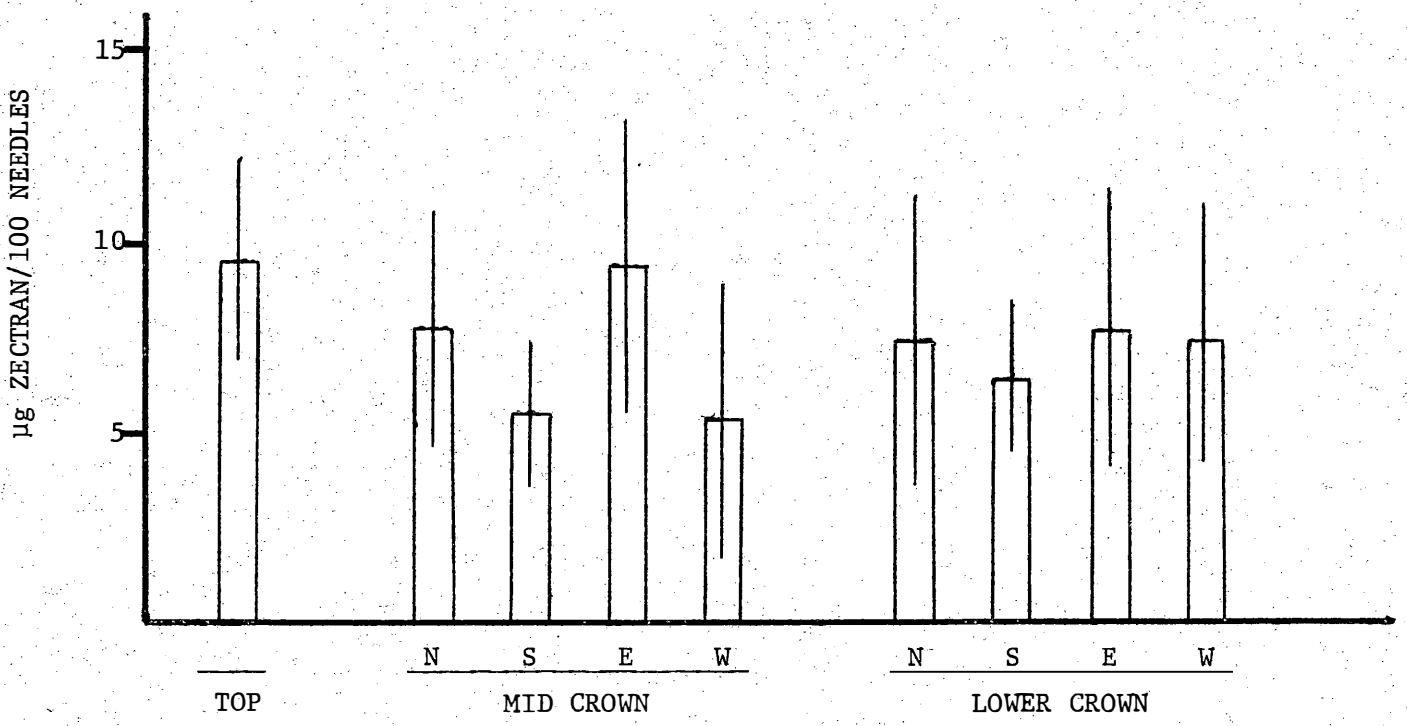

Figure 6.--The average deposit sampled within the various tree locations. The standard errors of the means are at the 90% probability level.

FIELD EXPERIMENT IN OREGON

In mid-July the results of the Zectran spraying at Riverside looked promising enough to conduct additional field experiments with this insecticide against later instar larvae of the Douglas-fir tussock moth.

OBJECTIVES. The specific objectives of the AAP for the field experiment were as follows:

1. To provide quantitative spray deposit assessment data for the evaluation of the treatments.
2. To detect the presence of possible drift in the control plot.

MATERIALS AND METHODS.

Area--The experiment was conducted against the rapidly expanding tussock moth outbreak in the LaGrande area of northeastern Oregon. This site was chosen because of the large insect population and the lack of evidence of any virus activity. The spray plots totaled about 1,550 acres of mixed true fir and Douglas-fir forest.

Design--Three plots, labeled 1Z, 2Z, and 3Z, were treated with Zectran between the dates July 22 and July 25. For plots 1Z and 2Z, the formulation contained 0.15 pound Zectran per gallon. The 3Z treatment plot received a formulation containing 0.3 pound Zectran per gallon. The application rate was one gallon per acre for all treatment plots. At the time the insecticide was applied, most of the larvae were in the fifth or sixth instar and were pupating at the lower elevations.

Equipment--A Bell helicopter equipped with conventional spray equipment was contracted for the tests. Twenty-two, 8003 TeeJet flat fan nozzles delivered the spray with a spray pressure of 60 psi. The nozzle orifices were directed downward 90° to the thrust line of the helicopter. The spraying speed was 45 mph.

Formulation--The Zectran formulation containing 0.15 pound Zectran per gallon, had been previously mixed in Missoula, Montana, for a different test that had been aborted. The formulation contained one part of Zectran FS-15 concentrate (Zectran in Dowanol TPM) mixed with nine parts fuel oil #2. The double dose formulation (0.3 lb Zectran/gallon) was prepared at LaGrande and consisted of two parts Zectran concentrate diluted with eight parts fuel oil #2. Approximately 1.0% w/v of DuPont Oil Red dye had been added to the formulation at Missoula for the deposit assessment.

Spray Application--The spray helicopter flew on the contour since all the treatment plots were on side hills. The swath spacing was approximately 100 feet, however, no swath markings or flagmen were used to indicate the swath spacings. The spraying height was about 50 feet above the trees.

Spray Deposit Sampling--The same sampling design was used in Oregon as was used in Washington (4 clusters of 10 trees each per plot). However, since no laboratory work had been done dealing with the removal of the DuPont Oil Red dye from the foliage, only aluminum plates and white cards were used to sample the spray deposit. The aluminum plates and white Kromekote cards were

positioned by the 40 sample trees per plot following the same sampling scheme used in Washington (two plates and one card under each tree, and two plates and a card in the nearest opening adjacent to each tree). Since plot 1Z was sprayed last and there was a shortage of aluminum plates, the deposit in only two of the 10-tree clusters was sampled with the plates. In the remaining two clustersof the plot, two white cards were placed under each tree, and two cards were placed in each corresponding open area.

Spray Drift Sampling--Twenty aluminum plates and 10 white cards were positioned in line, fifty feet apart, through the control (Check) plot.

Spray Deposit Analysis--The spray drops, on the four square centimeters in the center of each card, were counted with the aid of a dissecting microscope. These data gave the drop density (drops/sq cm) and were used to determine the spray atomization.

The spray deposit was washed from each aluminum plate with 10 ml. of reagent grade acetone. The concentration (g/ml) of dye was determined with a Beckman Spectrophotometer. The flourometer could not be used for the LaGrande data since the DuPont Oil Red dye was not a fluorescent material. The dye concentrations were corrected for background and recovery rate. The recovery rate was 98.2 ± 1.0%. The deposit was converted to gallons per acre by considering the actual concentration of

dye in the formulation, the deposit on the plates, and the surface area of the plate (equation 1).

RESULTS AND DISCUSSION

Atomization--An average mmd of 310 microns was obtained in the two plots sprayed at the 0.15 pound of Zectran per acre dose. In the 0.3 pound of Zectran per acre plot, the atomization was 312 microns.

These atomizations are consistantly coarser than those obtained in the Washington test with basically the same Zectran formulation, nozzle tips and spray pressure. This coarser atomization is most probably the result of two factors: the nozzle tip orientation and a restriction of flow rate. The restricted flow rate was caused by the plugging of filter screens and nozzle tips by the undisolved red dye in the formulation (approximately ten times too much dye had been added to the formulation).

Spray Deposit Assessment--The deposit data for the LaGrande experiment are summarized in Table 10. The individual data are tabulated in Appendixes F-H. As was the case in Washington, the average deposit was generally high (Table 10). The average deposit recovered from the aluminum plates that had been placed in the openings was 0.694 ± .127 gpa for plot 1Z, 0.325 ± .073 gpa for plot 2Z, and 0.123 ± .038 gpa for plot 3Z. The overall average deposit sampled in the open for the entire test was 0.316 gpa. It was not surprising that plot 3Z had the lowest deposit

Table 10.--Summary of the amount of spray deposit recovered from the aluminum plates and the number of drops on the white Kromekote cards. Zectran test, LaGrande, Oregon.

Plot	Cluster	Deposit			
		in the open		under the trees	
		gpa	drops/cm^2	gpa	drops/cm^2
1Z	1	.629 (.201)[a/]	62.0 (5.6)	.142 (.040)	41.4 (10.0)
	2	-	39.5 (12.3)	-	18.3 (3.8)
	3	-	90.1 (11.2)	-	55.9 (17.1)
	4	.759 (.184)	66.0 (18.8)	.296 (.208	49.0 (19.9)
2Z	1	-	-	-	-
	2	.258 (.108)	43.3 (10.8)	.064 (.028)	23.0 (8.8)
	3	.391 (.095)	15.4 (5.1)	.093 (.052)	13.3 (5.7)
	4	-	-	-	-
3Z	1	.286 (.090)	13.0 (4.0)	.089 (.046)	9.3 (5.1)
	2	.067 (.039)	6.0 (2.5)	.046 (.014)	2.2 (1.4)
	3	.065 (.014)	4.2 (1.9)	.049 (.020)	5.4 (2.4)
	4	.073 (.034)	7.7 (1.9)	.064 (.016)	6.0 (1.9)

a/The values in parentheses are the standard errors of the means at the 5 percent probability level.

since the sample clusters were positioned on a steep hillside, and a 6-8 mph wind was blowing up the hill at the time of application. (Wind speeds were measured by field crews using hand held Dwyer wind meters; no other meteorological conditions were recorded).

Since clusters #1 and #4 in plot 2Z were resprayed four days after the original application, no deposit data are available for those clusters. The cards and plates were collected after the first application and revealed for clusters #1 and #4 deposit which could be attributed only to drift.

Linear regression analysis showed there were high linear correlations between the deposit in the open (gpa) and the drop densities (drop/cm^2) for plots 1Z and 3Z: r=0.55 and 0.87, respectively. The linear regression was significant at the 0.05 level for plot 1Z and at the 0.01 level for plot 3Z. There was a low linear correlation between drop densities and the gpa for plot 2Z (r=0.08).

The deposit was consistant between clusters in plots 1Z and 2Z, with no significant (0.01 level) differences in the mean deposit (gpa) in the open among the cluster within each plot (Table 10). There was, however, a significant difference in deposit between the plots. There were also significant (0.01 level) differences in the average drops per square centimeter between clusters within plots 1Z and 2Z. In plot 1Z, cluster #3 had a greater density and cluster #2 a lower density of

drops than the other three clusters. In plot 2Z, cluster #2 had more drops/cm^2 than did cluster #3.

In plot 3Z, both the deposit (gpa in the open) and the drops/cm^2 in cluster #1 were significantly higher (0.01 level) than the other three clusters. It is interesting to note that cluster #1 was the upper most cluster, with the other clusters positioned downhill from it.

As was the case with the tests in Washington, there was significantly higher deposit recovered in the open, than under the trees (Appendixes F-H). The average atomization of the drops reaching the ground under the trees (238 mircons) was also finer than the average mmd in the open (311 microns). Drift Assessment--Since the concentration of DuPont Oil Red dye was measured with a spectrophotometer, which is 100 times less sensitive than a fluorometer, the low deposits at the drift level were undetectable.

CONCLUSIONS

In general, the deposit coverage in the Zectran treatment areas demonstrated the effectiveness of the aerial application technique. The adequate deposit achieved in the LaGrande tests, without swath markings, complimented the high deposit in the Washington tests where flagmen were used to mark the spray swaths. The consistent, relatively lower deposit resulting from the application of the pyrethrins at the 0.5 gallon per acre application rate, suggests that improved aerial application techniques must be developed before the lower application rates can be used effectively in the field.

If the pyrethrins-mineral oil formulation is to be further field tested, improvements are needed in the quantitative analysis methods, especially for analysis of the foliage samples. The tracer method previously developed for the Zectran formulation (Maksymiuk, et al., 1971) provided a simple, precise method for determining the Zectran deposit.

The small variation of deposit within the individual clusters indicates that the cluster method of sampling provides a good estimate of the deposit for the area around and within the cluster. The small differences in the mean deposit among the clusters shows that, if the cluster is to represent one datum point, the natural variations in the deposit will be small. If a large variation (100-1000 fold) in deposit is needed for a

field study, the deposit gradient will have to be applied; it will not result from the inherent variation of one application if the cluster method of sampling is used.

The results of the ten trees that were sampled at the top, midcrown, and lower crown levels indicated the reliability of the current sampling scheme of collecting the midcrown samples at the four cardinal directions. More tests of this type need to be conducted to constantly improve the sampling procedures.

Probably the most important aspect, of these tests, is the correlation of the mortality results from the airport tests with the actual mortalities from field experiments. Over a 100-foot spray swath, Zectran applications resulted in over 99 percent mortality, while pyrethrins treatments gave only 69 percent mortality over a same 100-foot swath during the airport tests. The Zectran treatment obviously resulted in the higher mortality under the specific conditions of the airport test. In the field experiment, one pyrethrins application resulted in 55 percent mortality, while one Zectran treatment provided over 80 percent mortality (Williams, 1972).

More experiments designed to illustrate such airport-field correlations need to be conducted to find the emperical relations between the two types of tests. In this particular set of tests, true comparisons cannot be made between the two insecticides, since no important application variable was

constant. For example, the Zectran concentration was 0.15 pound per gallon, while the pyrethrins concentration was 0.10 pound per gallon. The application rates were 1.0 and 0.5 gallons per acre for Zectran and pyrethrins, respectively, which resulted in dosages of 0.15 and 0.05 pound per acre, respectively. However, the good correspondence of the overall results of the airport and field experiments indicates the possible use of the airport tests for futher screening of insecticides before field tests are attempted.

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Williams, C. B.

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APPENDIX A

Deposit data from the

1972 Zectran test, Riverside, Washington

Tree no.	Deposit from foliage samples: Ave. wt./ 100 needles	Ave. g.dye/ml X10-8	Estimated µg. Zectran/ 100 needles	Deposit from aluminum plates & cards: In the open GPA	In the open Drops/ cm2	under trees GPA
RS 1	.5787	1.8542	3.3291	.5150	64.75	.1448
RS 2	.6521	1.1345	2.0369	.5039	71.25	.0877
RS 3	.5040	2.7115	4.8683	.4338	88.50	.1860
RS 4	.6677	3.0306	5.4412	.3719	63.00	.1899
RS 5	.5292	3.0653	5.5035	.5051	74.00	.1523
RS 6	.6492	7.4538	13.3827	.7565	116.50	.1951
RS 7	.6866	8.2967	14.8961	.7410	126.25	.1760
RS 8	.6245	10.8040	19.3977	.8025	127.25	.5123
RS 9	.7136	8.4820	15.2288	.7609	116.25	.2482
RS 10	.5690	7.9654	14.3012	.7363	109.50	.4120
RS 11	.8722	3.8329	6.8817	.3497	59.75	.4627
RS 12	.5343	6.6757	11.9857	.5868	51.75	.2121
RS 13	.5772	3.9497	7.0914	.4857	51.50	.2086
RS 14	.6042	5.3521	9.6093	.2657	42.50	.1502
RS 15	.7986	5.0858	9.1311	.5916	39.00	.2185
RS 16	.6240	5.2924	9.5021	.5218	51.25	.2090
RS 17	.6817	4.1973	7.5359	.5384	48.50	.3517
RS 18	.6689	7.3377	13.1742	.6062	37.00	.2137
RS 19	.6179	7.4682	13.4086	.6328	53.50	.4445
RS 20	.6799	6.3515	11.4036	.6673	51.25	.3842

Tree no.	Deposit from foliage samples			Deposit from aluminum plates & cards		
	Ave. wt./ 100	Ave. g.dye/ml X10^{-8}	Estimated µg. Zectran/ 100 needles	in the open		under trees
				GPA	Drops/ cm2	GPA
RS 21	.9216	1.2302	2.2087	.2375	64.25	.1463
RS 22	.5390	1.7455	3.1339	.2680	66.25	.1384
RS 23	.5946	2.3819	4.2765	.3485	88.25	.2740
RS 24	.6718	4.6233	8.3008	.4920	92.75	.1697
RS 25	.6035	.9671	1.7364	.4020	84.25	.1729
RS 26	.7027	3.8446	6.9027	.2954	70.50	.2423
RS 27	.5508	2.2256	3.9959	.4389	77.00	.0840
RS 28	.7286	3.3823	6.0726	.2652	59.75	.1971
RS 29	.6741	2.8188	5.0609	.3862	63.00	.1094
RS 30	.6006	2.0317	3.6478	.3921	74.25	.2050
RS 31	.7015	2.5020	4.4921	.5868	85.75	.1320
RS 32	.6584	1.8778	3.3714	.2839	71.25	.1990
RS 33	.7652	5.9984	10.7696	.3965	69.00	.0503
RS 34	.8367	4.9609	8.9069	.4766	79.50	.251
RS 35	.6812	3.1642	5.6811	.3786	74.75	.1305
RS 36	.6534	5.3717	9.6444	.6506	63.00	.2034
RS 37	.7377	1.2995	2.3331	.3263	74.00	.0941
RS 38	.5745	3.2236	5.7877	.5610	86.75	.2442
RS 39	.4649	6.0705	10.8991	.6633	84.75	.1187
RS 40	.6792	4.3756	7.8560	.5368	64.75	.2589

APPENDIX B

Spray deposit recovered from the foliage, after the Zectran application

Tree no.	Directional deposit							
	g. dye X10^{-7}/100 needles				g. dye X10^{-7}/0.5 g. foliage			
	North	South	East	West	North	South	East	West
RS 1	.8155	1.7511	3.3120	1.5384	.8434	1.3919	2.8046	1.2567
RS 2	1.3726	.9007	1.0026	1.2621	.8624	.7094	.9178	.9985
RS 3	1.2727	1.2940	4.0676	4.2118	1.5067	1.0940	4.2957	3.9805
RS 4	1.1983	3.7613	4.0309	3.1322	.8825	2.9721	3.2069	2.1421
RS 5	.7094	3.3120	1.9531	6.2867	.5792	3.2835	2.0583	5.9799
RS 6	8.1023	5.9408	4.6440	11.1283	9.4229	4.1793	3.0329	8.0524
RS 7	13.4335	5.9408	8.5346	5.2780	9.5337	4.0302	5.9912	4.4514
RS 8	7.8140	12.8575	8.2464	14.2984	7.8296	8.3252	6.0578	13.0887
RS 9	9.6297	1.5598	1.7256	21.0132	9.3600	.8334	1.9506	10.9226
RS 10	10.9842	5.1628	8.1023	7.6123	8.6280	5.0182	7.6647	6.3806
RS 11	2.6830	5.0474	2.0062	5.5950	1.4080	2.9840	1.1276	3.4918
RS 12	5.6527	8.2464	5.7103	7.0936	5.3762	7.1892	5.2129	7.2[illegible]
RS 13	4.7881	3.3719	4.3270	3.3120	4.4175	2.5805	3.5044	3.3371
RS 14	3.7014	5.4509	5.7967	6.4596	3.8464	5.1303	3.9510	4 [illegible]
RS 15	4.5576	7.8140	3.8212	4.1506	3.1511	4.8376	2.2759	2.5[illegible]
RS 16	4.6440	4.2693	6.6037	5.6527	4.0165	2.5829	4.8768	6.8[illegible]99
RS 17	3.2030	5.5086	5.1628	2.9148	2.3977	3.6274	4.2536	2.1036
RS 18	14.2984	4.3558	1.7299	8.9668	9.3597	6.0162	1.1081	5.8284
RS 19	4.3558	6.3731	7.7276	11.4164	3.6776	4.6479	6.7662	9.1616
RS 20	5.4221	5.2203	10.8401	3.9235	3.6534	4.2858	7.3094	3.1282

APPENDIX B (Cont.)

Tree no.	Directional deposit							
	g. dye X10^{-7}/100 needles				g. dye X10^{-7}/0.5 g. foliage			
	North	South	East	West	North	South	East	West
RS 21	1.0495	1.6022	1.2515	1.0176	.5947	.8707	.7342	.4929
RS 22	.6775	.5393	.4011	5.3644	.7550	.5135	.3444	4.4680
RS 23	3.9235	1.9531	1.9318	1.7192	2.9296	1.6087	1.8591	1.4764
RS 24	3.0125	1.8786	1.1770	12.4252	2.0843	1.3865	.9803	9.0405
RS 25	1.2089	.6775	.6349	1.3471	1.1997	.4995	.5733	.9928
RS 26	3.2521	5.2589	5.7967	1.0708	2.7779	3.7616	3.8420	.6933
RS 27	5.8178	1.6341	.7199	.7306	6.6637	1.2074	.6715	.6593
RS 28	2.6530	5.2289	1.6767	3.9709	1.8300	3.1462	1.4362	2.5616
RS 29	1.5491	3.4318	3.5216	2.7728	1.3230	2.6373	1.9048	2.5853
RS 30	1.6341	.5179	4.9893	.9857	1.2812	.5405	3.8836	.7659
RS 31	1.9531	2.6231	3.5216	1.9105	1.4740	1.6979	2.6651	1.3442
RS 32	3.4018	.6711	2.0487	1.3897	2.7279	.4790	1.4984	1.1096
RS 33	8.0446	5.3644	5.7103	4.8745	4.5041	4.5296	3.2297	3.5223
RS 34	7.5836	4.9322	1.9636	5.3644	5.1447	2.7551	1.1710	3.0607
RS 35	1.5598	3.2821	1.7299	6.0850	1.2701	2.0017	1.5660	4.1171
RS 36	4.9322	1.7511	3.0125	11.7911	4.2160	1.2711	2.3849	8.3209
RS 37	3.1023	.0715	.5817	1.4428	1.8654	.0505	.3754	1.1326
RS 38	8.8228	1.0069	.4117	2.6530	7.6626	.8246	.3473	2.5537
RS 39	6.0273	9.5432	3.2030	5.5086	6.2123	9.9860	3.4797	6.3095
RS 40	12.4252	1.8786	1.3216	1.8770	6.9817	1.7572	1.2756	1.2116

APPENDIX C

Deposit data from the first application,

1972 pyrethrins test, Oroville, Washington

Tree no.	Deposit from foliage samples			Deposit from aluminum plates & cards			
				In the open		Under the trees	
	Ave. wt./ 100 needles	Ave. g.dye/ml $X10^{-7}$	Estimated µg. Pyrethrins 100 needles	GPA	Drops/ cm^2	GPA	Drops/ cm^2
OS 1	.6661	1.0193	12.7886		2.25	.0100	2.00
OS 2	.5102	3.6873	46.2627		1.50	.0137	2.50
OS 3	.5468	0	0	.0205	2.25	.0019	4.00
OS 4	.6822	1.3274	16.6542	.0667	7.00	.0289	3.25
OS 5	.5428	.2981	3.7401	.0667	2.75	.0469	5.50
OS 6	.5759	.0875	1.0978	.0236	6.00	.0370	3.25
OS 7	.5649	.8139	10.2115	.0696	6.50	.0039	3.00
OS 8	.9137	.1595	2.0011	.0738	9.50	.0299	3.75
OS 9	.7386	.1922	2.4114	.0667	10.75	.0157	5.50
OS10	.6552	2.7649	34.6898	.0922	10.50	.0184	1.00
OS11	.7104	.1834	2.3010	.1107	28.00	.1117	22.25
OS12	1.1220	.6201	7.7800	.0887	16.00	.0551	6.25
OS13	.7361	.4167	5.2281	.2042	28.00	.0849	18.25
OS14	.5024	.1916	2.4039	.0132	4.50	.0734	19.00
OS15	.4076	.5954	7.4701	.2930	29.25	.0819	16.25
OS16	.6599	.3258	4.0876	.2189	11.75	.0061	5.75
OS17	.5942	0	0	.0193	6.50	.0022	3.00

APPENDIX C (Cont.)

Tree no.	Deposit from foliage samples			Deposit from aluminum plates & cards			
				In the open		Under the trees	
	Ave. wt./ 100 needles	Ave. g.dye/ml $X10^{-7}$	Estimated µg. pyrethrins 100 needles	GPA	Drops/ cm^2	GPA	Drops/ cm^2
OS 18	.6538	.3480	4.3661	.0536	9.75	.0221	6.00
OS 19	.5858	.0142	.1781	.0241	3.75	.0089	3.75
OS 20	.6954	.0263	.3299	.0649	7.25	.0019	2.75
OS 21	.7328	.2818	3.5356	.0904	16.75	.0663	19.50
OS 22	.5114	.0199	.2496	.0310	12.00	.0799	13.00
OS 23	.5631	0	0	.0996	20.00	.0215	9.75
OS 24	.7124	.0293	.3676	.0582	16.00	.0296	8.25
OS 25	.5839	.3867	4.8517	.0884	17.75	.0441	17.75
OS 26	.7035	.0320	.4014	.1234	21.00	.0544	15.00
OS 27	.4280	.0398	.4993	.	20.75	.0412	6.75
OS 28	.4938	.2161	2.7112	.1014	20.75	.0092	9.50
OS 29	.4123	0	0	.0944	2.75	.0082	16.50
OS 30	.3846	0	0	.1943	19.75	.0234	10.50
OS 31	1.0053	.0804	1.0087	.1260	13.50	.0450	3.25
OS 32	.6259	.0223	.2797	.0341	9.50	.0153	2.75
OS 33	.4486	.1153	1.4466	.1170	7.00	.0149	3.50
OS 34	.5427	.0800	1.0037	.0316	6.0	.0124	3.75
OS 35	.5060	0	0	.0384	8.25	.0138	8.00

APPENDIX C (Cont.)

Tree no.	Deposit from foliage samples			Deposit from aluminum plates & cards			
				In the open		Under the trees	
	Ave. wt./ 100 needles	Ave. g.dye/ml $X10^{-7}$	Estimated µg. pyrethrins 100 needles	GPA	Drops/ cm^2	GPA	Drops/ cm^2
OS 36	.5342	.0506	.6348	.0320	6.25	.0388	4.75
OS 37	.6371	.0064	.0802	.0123	3.50	.0081	3.00
OS 38	.7833	.1861	2.3349	.0327	8.50	.0110	4.75
OS 39	.9630	.0587	.7364	.0012	3.50	.0033	4.25
OS 40	.5522	.0074	.0928	.0120	5.75	.0040	5.25

APPENDIX D

Deposit data from the second application,

1972 pyrethrins test, Orovill e, Washington

Tree no.	Deposit from aluminum plates and white cards			
	samples in the open		samples under trees	
	gpa	drops/cm^2	gpa	drops/cm^2
OS 1	.0087	3.25	.0063	1.25
OS 2	.0120	0.50	.0025	1.00
OS 3	.0109	2.00	.0076	1.50
OS 4	.0739	3.25	.0089	4.00
OS 5	.0013	4.00	.0431	8.50
OS 6	.0281	3.25	.0254	9.25
OS 7	.0083	8.50	.0219	6.75
OS 8	.0231	3.50	.0352	4.25
OS 9	.0744	8.00	.0471	2.00
OS 10	.1233	3.00	.0083	1.25
OS 11	.0753	20.75	.0785	7.75
OS 12	.1641	28.00	.0638	21.50
OS 13	.0033	2.75	.0452	17.50
OS 14	.1631	19.50	.0961	13.00
OS 15	.0063	11.00	.0063	12.75
OS 16	.1720	27.25	.0703	17.50
OS 17	.0431	36.00	.0732	8.00
OS 18	.1383	30.75	.0732	24.00
OS 19	.1333	11.00	.0409	12.50
OS 20	.1150	28.50	.0157	4.75

APPENDIX D (Cont.)

Tree no.	Deposit from aluminum plates and white cards			
	samples in the open		samples under trees	
	gpa	drops/cm^2	gpa	drops/cm^2
OS 21	.0896	18.25	.0581	7.75
OS 22	.0793	missing	.0703	11.00
OS 23	.0989	22.50	.0324	14.50
OS 24	.1168	17.75	.0603	18.75
OS 25	.1397	21.25	.0624	16.25
OS 26	.0514	8.00	.0029	7.75
OS 27	.0053	3.50	.0087	6.50
OS 28	.0119	19.25	.0008	7.50
OS 29	.0524	13.75	.0164	6.50
OS 30	.0162	14.50	.0269	16.25
OS 31	.0303	1.00	.0041	1.00
OS 32	.0238	6.25	.0288	5.00
OS 33	.0341	3.75	.0031	1.50
OS 34	.0438	18.25	.0474	11.00
OS 35	.0405	12.25	.0388	5.75
OS 36	.0886	15.50	.0495	20.00
OS 37	.0288	7.75	.0311	11.50
OS 38	.0767	24.75	.0404	10.00
OS 39	.0170	7.25	.0200	9.50
OS 40	.0682	17.75	.0577	19.50

APPENDIX E

Spray deposit recovered from the foliage after the first pyrethrins application.

Tree no.	Directional deposit							
	g. dye X10^{-6}/100 needles				g. dye X10^{-6}/0.5 g. foliage			
	North	South	East	West	North	South	East	West
OS 1	0	4.0462	.0312	0	0	3.5473	.0245	0
OS 2	10.3755	2.6862	1.5704	.1174	8.5732	2.5454	1.4981	.1529
OS 3	0	0	0	0	0	0	0	0
OS 4	1.0391	2.9837	.9860	.3009	.8469	2.3753	.7025	.1914
OS 5	.3925	.4087	.0473	.3439	.2370	.4362	.0473	.4579
OS 6	0	.2124	.0744	.0635	0	.5795	.0740	.0485
OS 7	0	.9647	.9860	1.3049	0	.8573	.7952	1.2039
OS 8	0	.4411	.0473	.1499	0	.3325	.0343	.0572
OS 9	.0258	.6354	.0119	.0959	.0174	.4328	.0076	.0685
OS 10	1.1454	.8267	.8267	8.2610	.9719	.5792	.5993	6.5691
OS 11	.3547	.1983	.1714	.0095	.2580	.1331	.1291	.0063
OS 12	1.3184	.2145	.5930	.3547	.7238	.0792	.3067	.1409
OS 13	.2738	.3547	.6461	.3925	.1457	.2352	.6053	.2735
OS 14	.0204	.2200	.2523	.2738	.0195	.2240	.2173	.3288
OS 15	.3871	.8267	.6567	.5110	.3593	1.2589	.9256	.6252
OS 16	.0937	.1336	1.0180	.0581	.0617	.0873	.7758	.0631
OS 17	0	0	0	0	0	0	0	0
OS 18	.0744	.2360	.9860	.0959	.0552	.2009	.7334	.0702
OS 19	0	.0527	0	.0041	0	.0487	0	.0029
OS 20	.0635	0	0	.0419	.0346	0	0	.0328

APPENDIX E (Cont.)

Tree no.	Directional deposit							
	g. dye X10^{-6}/100 needles				g. dye X10^{-6}/0.5 g. foliage			
	North	South	East	West	North	South	East	West
OS 21	.1445	.1929	.6885	.1013	.0986	.1389	.5674	.0563
OS 22	.0796	0	0	0	.0605	0	0	0
OS 23	0	0	0	0	0	0	0	0
OS 24	0	.1174	0	0	0	.0790	0	0
OS 25	.5975	.1875	.7523	.0095	.5647	.1489	.5646	.0092
OS 26	0	0	.1282	0	0	0	.0678	0
OS 27	0	.1174	0	.0419	0	.1295	0	.0487
OS 28	.2792	0	.4734	.1119	.1855	0	.4338	.1663
OS 29	0	0	0	0	0	0	0	0
OS 30	0	0	0	0	0	0	0	0
OS 31	.0419	.1067	.0937	.0796	.0183	.0591	.0450	.0425
OS 32	.0635	0	0	.0258	.0423	0	0	.0198
OS 33	.2955	0	0	.1660	.2125	0	0	.2017
OS 34	.0850	.1660	.0690	0	.0766	.1571	.0772	0
OS 35	0	0	0	0	0	0	0	0
OS 36	.0796	0	.1228	0	.0498	0	.0900	0
OS 37	0	.0258	0	0	0	.0173	0	0
OS 38	.0904	.1282	.3816	.1445	.0525	.0653	.3091	.0943
OS 39	.1714	0	.0635	0	.0591	0	.0269	0
OS 40	0	.0204	.0095	0	0	.0159	.0100	0

APPENDIX F

Deposit data from spray plot 1Z, Zectran concentration: 0.15 lb Zectran/gal.

1972 Zectran test, LaGrande, Oregon.

Tree no.	Deposit from aluminum plates and white cards: samples in the open		samples under trees	
	gpa	drops/cm^2	gpa	drops/cm^2
1Z 1	.5739	65.75	.1779	35.25
1Z 2	.8303	61.25	.1867	68.50
1Z 3	1.0185	52.00	.1438	44.50
1Z 4	.2688	61.00	.1231	43.25
1Z 5	.2818	60.50	.2561	47.00
1Z 6	.8725	66.25	.0726	19.00
1Z 7	.8238	66.50	.1072	38.00
1Z 8	.8400	78.50	.1471	26.50
1Z 9	.3077	53.25	.1477	55.00
1Z 10	.4700	55.50	.0580	37.25
1Z 11		42.62		20.88
1Z 12		30.50		30.88
1Z 13		23.75		21.50
1Z 14		35.75		14.75
1Z 15		68.00		18.62
1Z 16		52.12		13.62
1Z 17		57.25		16.50
1Z 18		48.25		15.25
1Z 19		22.38		18.62
1Z 20		14.12		13.25

Tree no.	Deposit from aluminum plates and white cards: samples in the open		samples under trees	
	gpa	drops/cm^2	gpa	drops/cm^2
1Z 21		82.88		34.62
1Z 22		62.12		55.12
1Z 23		110.50		29.25
1Z 24		104.38		45.12
1Z 25		90.88		86.88
1Z 26		71.38		78.25
1Z 27		105.50		42.50
1Z 28		100.75		60.38
1Z 29		83.75		96.00
1Z 30		88.75		30.88
1Z 31	.6323	37.50	.1747	48.00
1Z 32	.3483	33.25	.0350	19.00
1Z 33	.5090	65.75	.2250	38.75
1Z 34	.8238	77.75	.1091	60.75
1Z 35	.9601	84.50	.2964	74.25
1Z 36	.8984	96.75	.9212	75.25
1Z 37	.9049	88.25	.5328	54.75
1Z 38	1.2295	79.75	.5641	92.50
1Z 39	.5447	20.00	.0627	11.00
1Z 40	.7362	76.75	.0439	15.75

APPENDIX G

Deposit data from spray plot 2Z, Zectran concentration: 0.15 lb Zectran/gal

1972 Zectran test, LaGrande, Oregon.

Tree no.	Deposit from aluminum plates and white cards: samples in the open		samples under trees	
	gpa	drops/cm^2	gpa	drops/cm^2
2Z 11	.1707	27.00	.0478	18.50
2Z 12	.1313	33.00	.0305	22.75
2Z 13	.1589	39.50	.0982	36.75
2Z 14	.2002	46.00	.0586	28.50
2Z 15	.0623	23.25	.0270	10.00
2Z 16	.1628	33.25	.0218	4.75
2Z 17	.4130	52.25	.1126	41.00
2Z 18	.3539	70.75	.0879	31.75
2Z 19	.5214	60.50	.1293	27.00
2Z 20	.4071	47.50	.0240	9.00
2Z 21	.5588	21.00	.2523	28.00
2Z 22	.5470	24.75	.1057	25.75
2Z 23	.5549	20.75	.0569	15.00
2Z 24	.3244	22.50	.1835	2.00
2Z 25	.4445	14.25	.0262	8.50
2Z 26	.2318	7.50	.0571	10.25
2Z 27	.3421	19.75	.0803	8.75
2Z 28	.2219	8.00	.0801	13.25
2Z 29	.4268	7.50	.0813	13.00
2Z 30	.2617	8.00	.0110	8.50

APPENDIX H

Deposit data from spray plot 3Z, Zectran concentration: 0.30 lb Zectran/gal

1972 Zectran test, LaGrande, Oregon

Tree no.	Deposit from aluminum plates and white cards			
	samples in the open		samples under trees	
	gpa	drops/cm^2	gpa	drops/cm^2
3Z 1	.4982	23.50	.1376	7.75
3Z 2	.3783	14.50	.0350	4.50
3Z 3	.4014	19.75	.1679	26.25
3Z 4	.1195	4.50	.1048	12.00
3Z 5	.3698	15.25	.0354	11.50
3Z 6	.1795	12.50	.0518	8.25
3Z 7	.1795	7.25	.0503	3.25
3Z 8	.2436	12.00	.0523	2.50
3Z 9	.3278	11.00	.2201	13.50
3Z 10	.1580	10.25	.0392	3.25
3Z 11	.0278	6.25	.0201	1.00
3Z 12	.0337	6.50	.0411	1.25
3Z 13	.0448	6.00	.0491	1.50
3Z 14	.0221	1.25	.0659	5.00
3Z 15	.0814	6.75	.0480	1.75
3Z 16	.0539	5.00	.0589	1.25
3Z 17	.0472	2.75	.0364	1.50
3Z 18	.0436	2.00	.0333	1.00
3Z 19	.1153	11.75	.0232	1.00
3Z 20	.2037	11.25	.0859	6.75

APPENDIX H (Cont.)

Deposit from aluminum plates and white cards

Tree no.	samples in the open		samples under trees	
	gpa	drops/cm^2	gpa	drops/cm^2
3Z 21	.0501	0.50	.0313	1.75
3Z 22	.0524	1.50	.0491	1.00
3Z 23	.0564	4.00	.0334	10.00
3Z 24	.0512	6.25	.0209	4.50
3Z 25	.0453	4.50	.0385	4.75
3Z 26	.0465	2.75	.0701	6.75
3Z 27	.0974	7.25	.1000	5.75
3Z 28	.0966	8.00	.0911	11.50
3Z 29	.0636	5.75	.0345	4.00
3Z 30	.0922	1.25	.0174	3.50
3Z 31	.1090	9.00	.0412	5.00
3Z 32	.0928	7.25	.0343	7.50
3Z 33	.1870	13.75	.1090	7.75
3Z 34	.0472	9.25	.0606	9.75
3Z 35	.0688	6.00	.0358	missing
3Z 36	.0273	6.25	.0669	3.00
3Z 37	.0512	4.75	.0701	5.25
3Z 38	.0787	8.50	.0859	10.75
3Z 39	.0244	7.50	.0806	3.75
3Z 40	.0417	4.50	.0600	7.50